MEMO

Date: January 8, 2021
To: Board of Directors
From: Dan Rubado, Evaluation Project Manager
Subject: Summary of Single-Family Low Flow Gas Showerhead Analysis Results

The attached Low Flow Gas Showerhead Analysis report describes a utility billing analysis that was conducted to determine the amount of gas savings realized from showerheads and shower wands included in Energy Saver Kits (ESKs). The analysis focused on ESKs including water saving measures that were shipped to single-family homes with gas water heat, located in Energy Trust's gas service territory, from 2013 to 2018. Energy Trust used an analysis platform developed by Recurve Analytics to perform weather normalization, apply analysis parameters, select a comparison group of similar homes, and compute overall ESK gas savings estimates. Energy Trust then used the site-level outputs from the platform to conduct further analysis.

The analysis found that overall gas savings for ESKs shipped from 2013 to 2018 were near zero. Further analysis showed that while no gas savings were detectable from 2013 to 2016, significant savings were realized between 2017 and 2018. Although it is surprising that ESKs yielded no gas savings for a four-year period, after which savings suddenly appeared in 2017 and 2018, there are plausible explanations for this observation. The reversal in realized savings coincided with a major shift in Energy Trust's ESKs. A new, higher quality type of showerhead product was introduced into the kits in 2017 and shower wands made their ESK debut that year. Around this same time, the ESK online order form was adjusted so that customers had to proactively select showerheads and wands, rather than being included by default. The change in order form may have resulted in more intentional action by customers that needed and wanted to install a new, low-flow device. These program changes have been maintained since that time. Although the headline finding from this analysis is that ESKs had no detectable savings overall, we can draw the most salient lessons from the 2017 and 2018 results, which reflect the most recent ESK design and delivery. Energy Trust should use these results to develop new showerhead and shower wand measures for future efforts.

During the 2017 and 2018 program years, ESKs included only showerheads and wands with rated maximum flow rates of 1.75 gallons per minute. Of the kits analyzed during this period, more than 80 percent included showerheads and 50 percent included shower wands. For kits that contained showerheads, there was an average of 1.5 showerheads included. Only 1 shower wand was included per kit, for those containing wands. The deemed gas savings claimed per device from 2017 to 2018, was 9.2 therms for shower wands. Showerheads had two different deemed savings values that were used during this period—8.1 and 9.2 therms. The weighted average deemed savings per showerhead was 8.9 therms, based on kit volume. In addition, nearly all kits included faucet aerators, which were associated with significant deemed gas savings, and most included LEDs, which had minor negative gas interactions. The analysis was not able to assess the independent contributions of aerators or LEDs on ESK savings. However, based on the 2013 to 2016 results, we hypothesize that both aerators and LEDs had minimal

impact on gas usage and that the appearance of gas savings in 2017 and 2018 was due to changes in the showerhead and shower wand offerings.

For ESKs shipped in 2017 and 2018, the analysis shows that kits including showerheads resulted in 4.4 therms of savings and shower wand resulted in 7.7 therms of additional savings. However, these savings values are per ESK shipped and do not account for the number of devices included nor their installation rate. To obtain savings values per device installed, we applied adjustment factors for the average number of devices included per kit (noted above) and the installation rate for those devices (55 percent)[1]. We applied these adjustment factors using the following equations.

Showerheads:

- 4.4 therms per kit / 1.5 devices per kit = 2.9 therms per device shipped
- 2.9 therms per device shipped / 0.55 installation rate = 5.3 therms per showerhead installed

Shower wands:

- 7.7 therms per kit / 1.0 device per kit = 7.7 therms per device shipped
- 7.7 therms per device shipped / 0.55 installation rate = 14.1 therms per shower wand installed

These savings values are summarized in Table 1, below.

Table 1: Evaluated savings estimates for showerhead and shower wand components of ESKs, 2017 to 2018

Device Type	Savings per Kit Shipped (therms)	Average Devices per Kit	Savings per Device Shipped (therms)	Installation Rate	Savings per Device Installed (therms)
Showerhead	4.4	1.5	2.9	55%	5.3
Shower wand	7.7	1.0	7.7	55%	14.1

Results from this impact evaluation can inform savings analysis for future showerhead and shower wand measures by applying realization rates[2] to deemed savings values developed through engineering calculations. Using a realization rate approach to calibrate deemed savings will allow us to apply the findings from the impact evaluation to different scenarios without needing to investigate all of the underlying assumptions that go into the engineering calculations. The deemed savings values for showerheads and wands (noted above) already have an installation rate adjustment applied, so they represent the savings per device shipped. To compute realization rates, we must directly compare the deemed savings values with the evaluation results in the same units. To do this, we must remove the installation rate adjustment from the deemed values, so they represent the savings per device installed. In 2017 and 2018, the deemed showerhead and shower wand measures used an installation rate assumption of 64.2%, which was baked into the deemed savings values. Removing the installation rate

[1] Installation rates were estimated based on a series of surveys conducted with ESK recipients after they received their kits. Questions collected information about what items recipients had installed and what they planned to install. Three surveys collected data at three different time points from 2013 to 2018.

[2] A realization rate is a ratio of measured or evaluated savings (often called ex-post) relative to the claimed or deemed energy savings (often called ex-ante). For this analysis, the realization rate does not include free ridership or spillover.

results in deemed savings values of 13.9 therms per showerhead installed and 14.3 therms per shower wand installed.

The overall realization rate for showerheads, assuming deemed savings of 13.9 therms per device installed, is 38 percent. The realization rate for shower wands, assuming deemed savings of 14.3 therms per device installed, is 99 percent. These results are summarized in Table 2, below.

Table 2: Realization rates for showerhead and shower wands compared to deemed savings, 2017 to 2018

Device Type	Deemed Savings per Device Shipped (therms)	Assumed Installation Rate	Deemed Savings per Device Installed (therms)	Evaluated Savings Per Device Installed (therms)	Realization Rate
Showerhead	8.9	64.2%	13.9	5.3	38%
Shower wand	9.2	64.2%	14.3	14.1	99%

The results of the gas showerhead impact evaluation will be applied to Energy Trust's annual true-up process, in which past program savings results are corrected based on improved information and evaluation results. For the true-up, all faucet aerator gas and electric savings from 2013 to 2018 will be zeroed out. Gas and electric savings for all showerheads installed from 2013 to 2016 will also be zeroed out. Showerheads installed from 2017 to 2018 will have their gas and electric savings adjusted to between 31 and 35 percent of the original savings claimed, depending on the deemed savings values for the measures used at the time. Shower wands installed from 2017 to 2018 will have their gas and electric savings adjusted to between 75 and 110 percent of the original savings claimed, again, depending on the deemed savings values used at the time.

Although showerheads realized much higher savings in the 2017 to 2018 period than they did prior to that, they still performed poorly compared to expectations and relative to shower wands. This is likely a result of several programmatic and customer factors, such as differences in the number of items shipped, installation rates, installation into primary shower locations, usage patterns, and baseline flow rates. These factors would be impossible to disentangle through billing analysis.

The analysis also found several factors that appeared to influence the realized savings for showerheads. Smaller homes (less than 1,200 square feet), older homes (built before 1930), homes with high gas usage (above 810 therms per year), and homes located in Southwest Washington, all showed slightly higher showerhead savings than the overall average. These results may be due to customer factors that are key to showerhead savings, such as fewer secondary showers, higher baseline flow rates, and higher occupancy and shower usage. They may also be due to random variations in gas usage for different customer groups. Although these findings are indicative of certain scenarios where showerheads achieved higher savings than the overall average, the results are not precise enough to infer exact savings values. In other words, we would expect somewhat higher savings for showerheads installed in these scenarios, but we don't have reliable estimates for how much higher.

Shower wand savings were generally high across many factors. It was more difficult to assess differences in shower wand savings for different scenarios, due to lower sample sizes and higher variance. Although there were some large differences in shower wand savings, the patterns were not as clear and we had lower confidence in the results. However, a few findings stood out. Smaller homes (less than 1,200 square

feet), homes with high gas usage (above 810 therms per year), and homes located in Central or Eastern Oregon, all showed higher shower wand savings than the overall average. Although we might expect higher savings for shower wands in these scenarios, we don't have reliable estimates for how much higher.

Low Flow Gas Showerhead Analysis

Tillman Degens and Gina Saraswati for Dan Rubado, Energy Trust of Oregon

9/18/2020

Contents

1 Background and Introduction

Low flow showerheads and shower wands are major gas and electric efficiency measures that have been the backbone of Energy Trust's residential program cost-effectiveness for the past decade. These devices are simple, relatively inexpensive, easy to install, and durable.The technology has been very stable over the past 30 years with relatively little technical design innovation. These devices save energy in homes by reducing the flow rate of hot water during a shower, theoretically reducing the amount of hot water used in a home. The amount of hot water saved, and thus energy, is dependent on the utilization level of an individual shower and the percent reduction in water flow achieved by the efficient device installed in the shower. It also depends on the behavioral response of the occupants and whether they change their shower length or frequency after installing the low flow device.

Approximately 30,000 homes were identified to which Energy Trust had sent an Energy Saver Kit (ESK), containing a showerhead or shower wand, from 2013 to 2018. The inclusion criteria were:

- ESK with low flow device sent to an individual address
- Single-family site built or manufactured homes
- Gas water heating fuel

Energy Trust's online impact evaluation platform, developed by Recurve Analytics was used to match the ESK project sites to gas utility billing data. The focus was on gas savings in homes with gas water heating fuel to simplify the analysis. The Recurve platform was used to conduct three primary analytical tasks:

- Develop a matched comparison group and future participant comparison group
- Develop weather normalized annual gas usage estimates for all participant and comparison group homes for the baseline and
- Estimate the overall gas impact of ESKs containing low flow devices sent to single-family homes with gas water heating fuel

The purpose of this report is initial exploratory analysis to assess the OpenEE data provided by Recurve as well as information from ETO's Project Tracking data to evaluate the overall gas savings for residential showerheads while isolating the impact from other measures that were installed at each home.

1.1 Research Goals

- Determine the overall average annual gas savings per showerhead (all types included in an ESK)
  - Per showerhead shipped
- Determine the average annual gas savings per device shipped and per device installed by:
  - Product type (showerhead versus shower wand)
  - Installation period
  - Home size category
  - Home type (site built versus manufactured homes)(This was taken out due to insufficient data)
  - Home vintage category
  - Gas usage category
  - Geographic region
  - Household demographic factors (e.g., income category, number of occupants)

2 Data Description and Summary Statistics

The data used in this analysis comes from 3 main sources:

- The original Recurve dataset which includes estimated annualized therms that are calculated from the site-level regression coefficients using TMY3 data as the weather inputs. Each row of observation has a unique alphanumeric site ID which can be matched to the same site within Energy Trust's internal data warehouse.
- Site characteristic information from CRM and PT such as square footage and building vintage. This information can be matched to the sample from the Recurve data based on the site ID.
- Census tract level information for average household size and median household income based on ACS 2018

2.1 Description of Data

Description of some of the fields within the Recurve Dataset:

- site = unique alphanumeric site ID that can be matched to UCI and Project Tracking
- baseline_base_load = weather normalized (using TMY3) annual base load gas consumption in therms during the baseline period (12 calendar months prior to intervention)
- baseline_predicted_usage = weather normalized annual gas consumption in therms during the baseline period
- reporting_base_load = weather normalized annual base load gas consumption in therms during the reporting period (12 calendar months following the intervention)
- reporting_predicted_usage = weather normalized annual gas consumption in therms during the reporting period
- modeled_savings = weather normalized change in annual gas consumption in therms, aka DNAC, from baseline period to reporting period
- portofolio_type = site type of the home (treated, potential control, future participant)

Note that: modeled_savings = reporting_predicted_usage - baseline_predicted_usage

Study Group Definitions (portofolio_type):

- treatment = the treatment group consists of participant homes that received an ESK.
  - These may be referred to as participants, ESK recipients, or treatment homes, interchangeably.
- individual_matched = the site-level matched non-participant comparison group.
  - These homes were selected from a large pool of candidate residential sites with gas utility meters from Energy Trust's Utility Customer Information (UCI) database that did not receive an ESK.
  - These homes did not participate in any measures during the analysis period.
  - Non-participant comparison sites were matched to each treatment site based on their monthly gas consumption in the baseline period.
  - Candidate non-participant homes were matched to each treatment home, based on baseline period monthly gas consumption.
  - For each treatment home, the five closest matches within the same zip code were selected to form the comparison group.
- stratified_future_participants = for each portfolio year of treatment sites, participants from future years, i.e. the following two years (skipping the year immediately following the intervention) are selected as a comparison group.

- Once the pool is identified for a given program year, stratified sampling is used to select a subset of future participants that has a baseline annual gas usage distribution similar to the treatment group.
- This group of future participants is then used as an alternative comparison group, when the sample size is sufficient. Gas usage for the future participant comparison group homes is analyzed for the same time period as the treatment homes, prior to ESKs being delivered to them.
- The primary benefit is that it is composed of homes that participated in the same measure in a different year, so it eliminates selection bias. Using this group gives us a form of experimental study design. Sometimes the number of future participant sites is not sufficient to conduct a robust analysis, though, and other times the program has changed sufficiently over time that they aren't that representative of past participant sites.

2.2 Summary Statistics

Table 1: Number of Sites in Each Study Group Within Recurve Sample

Site Type	n	Percent
individual_matched	97,837	74.76%
stratified_future_participants	12,857	9.82%
treatment	20,175	15.42%
Total	130,869	100.00%

Table 2: Number of Treated and Control Sites in each Portfolio Year

InstalledYear	individual_matched	stratified_future_participants	treatment	Total
2013	16,788 (17.16%)	3,198 (24.87%)	3,468 (17.19%)	23,454 (17.92%)
2014	32,525 (33.24%)	3,096 (24.08%)	6,625 (32.84%)	42,246 (32.28%)
2015	20,273 (20.72%)	2,862 (22.26%)	4,127 (20.46%)	27,262 (20.83%)
2016	13,697 (14.00%)	2,564 (19.94%)	2,805 (13.90%)	19,066 (14.57%)
2017	10,621 (10.86%)	1,137 (8.84%)	2,326 (11.53%)	14,084 (10.76%)
2018	3,933 (4.02%)	0 (0.00%)	824 (4.08%)	4,757 (3.63%)
Total	97,837 (100.00%)	12,857 (100.00%)	20,175 (100.00%)	130,869 (100.00%)

Table 3: Weather Normalized (TMY3) Predicted Annual Therms

portfolio_type	N	Mean	Max	Min	Sum	StdDev
Baseline Period						
individual_matched	97,837	662.2276	1,523.296	17.649240	64,790,361	246.3039
stratified_future_participants	12,857	665.7038	1,735.222	3.989027	8,558,954	259.7967
treatment	20,175	667.3340	1,740.416	35.337570	13,463,463	256.8968
Reporting Period						
individual_matched	97,837	672.1251	2,197.092	3.299722	65,758,700	255.4668
stratified_future_participants	12,857	672.6153	2,368.972	2.966906	8,647,815	264.3840
treatment	20,175	675.7222	2,765.146	20.081255	13,632,695	265.1426

Table 4: Weather Normalized Modeled Annual Savings in Therms

Site Type	N	mean	max	min	sum	sd
individual_matched	97,837	-9.897467	1,070.888	-887.3827	-968,338.5	83.05394
stratified_future_participants	12,857	-6.911527	1,155.840	-868.7283	-88,861.5	100.82974
treatment	20,175	-8.388163	1,202.455	-1,209.9530	-169,231.2	106.55154

Table 5: Shower Heads by Installation Year

InstalledYear	0	1	2	4	6	Total
2013	42 (7.65%)	738 (15.00%)	2,680 (18.23%)	7 (100.00%)	1 (100.00%)	3,468 (17.19%)
2014	31 (5.65%)	1,510 (30.69%)	5,084 (34.59%)	0 (0.00%)	0 (0.00%)	6,625 (32.84%)
2015	2 (0.36%)	847 (17.22%)	3,278 (22.30%)	0 (0.00%)	0 (0.00%)	4,127 (20.46%)
2016	0 (0.00%)	487 (9.90%)	2,318 (15.77%)	0 (0.00%)	0 (0.00%)	2,805 (13.90%)
2017	308 (56.10%)	937 (19.04%)	1,081 (7.35%)	0 (0.00%)	0 (0.00%)	2,326 (11.53%)
2018	166 (30.24%)	401 (8.15%)	257 (1.75%)	0 (0.00%)	0 (0.00%)	824 (4.08%)
Total	549 (100.00%)	4,920 (100.00%)	14,698 (100.00%)	7 (100.00%)	1 (100.00%)	20,175 (100.00%)

Table 6: Shower wands by Installation Year

InstalledYear	0	1	2	3	4	6	Total
2013	3,393 (18.29%)	46 (2.89%)	24 (82.76%)	1 (100.00%)	3 (100.00%)	1 (100.00%)	3468 (17.19%)
2014	6,572 (35.43%)	48 (3.01%)	5 (17.24%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	6625 (32.84%)
2015	4,124 (22.24%)	3 (0.19%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	4,127 (20.46%)
2016	2,805 (15.12%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	2,805 (13.90%)
2017	1,338 (7.21%)	988 (61.98%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	2,326 (11.53%)
2018	315 (1.70%)	509 (31.93%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	824 (4.08%)
Total	18,547 (100.00%)	1,594 (100.00%)	29 (100.00%)	1 (100.00%)	3 (100.00%)	1 (100.00%)	20,175 (100.00%)

Analysis Groups

The three groups, treatment, matched and future participants all had building and demographics data drawn from Energy Trust's customer relations management (CRM) database. It is expected that the treatment and future participants will have similar levels CRM data available. The matched participant group is expected to have lower levels of building characteristics data available as this group of households have not all participated in Energy Trust programs. However, a significant number has participated in one or another Energy Trust program over time and the CRM data will include this data. This means for models including square footage or building type variables the matched participant group will only include those households for which the CRM had data available

Table 7: Installation Year for each Site Type

InstalledYear	individual_matched	stratified_future_participants	treatment	Total
2013	16788 (17.16%)	3198 (24.87%)	3468 (17.19%)	23454 (17.92%)
2014	32525 (33.24%)	3096 (24.08%)	6625 (32.84%)	42246 (32.28%)
2015	20273 (20.72%)	2862 (22.26%)	4127 (20.46%)	27262 (20.83%)
2016	13697 (14.00%)	2564 (19.94%)	2805 (13.90%)	19066 (14.57%)
2017	10621 (10.86%)	1137 (8.84%)	2326 (11.53%)	14084 (10.76%)
2018	3933 (4.02%)	0 (0.00%)	824 (4.08%)	4757 (3.63%)
Total	97837 (100.00%)	12857 (100.00%)	20175 (100.00%)	130869 (100.00%)

Table 8: Water Heating Fuel

Water Heating Fuel (SitesPT)	Not Likely Gas (Recurve)	Likely Gas (Recurve)	Total
ELE	101 (12.67%)	5632 (4.33%)	5733 (4.38%)
GAS	137 (17.19%)	65349 (50.24%)	65486 (50.04%)
Oil	0 (0.00%)	1 (0.00%)	1 (0.00%)
Propane	0 (0.00%)	1 (0.00%)	1 (0.00%)
Solar	3 (0.38%)	37 (0.03%)	40 (0.03%)
NA	556 (69.76%)	59052 (45.40%)	59608 (45.55%)
Total	797 (100.00%)	130072 (100.00%)	130869 (100.00%)

Table 9: Other Measures Installed

HasOtherGasMeasure	individual_matched	stratified_future_participants	treatment	Total
FALSE	97837 (100.00%)	12857 (100.00%)	0 (0.00%)	110694 (84.58%)
TRUE	0 (0.00%)	0 (0.00%)	20175 (100.00%)	20175 (15.42%)
Total	97837 (100.00%)	12857 (100.00%)	20175 (100.00%)	130869 (100.00%)

Table 10: Study Groups by Region

Region	individual_matched	stratified_future_participants	treatment	Total
Central Oregon	2526 (2.58%)	410 (3.19%)	522 (2.59%)	3458 (2.64%)
Eastern Oregon	740 (0.76%)	80 (0.62%)	153 (0.76%)	973 (0.74%)
North Coast	2444 (2.50%)	276 (2.15%)	493 (2.44%)	3213 (2.46%)
Portland Metro & Hood River	65875 (67.33%)	8798 (68.43%)	13602 (67.42%)	88275 (67.45%)
Southern Oregon	709 (0.72%)	89 (0.69%)	146 (0.72%)	944 (0.72%)
Southwest Washington	2354 (2.41%)	267 (2.08%)	476 (2.36%)	3097 (2.37%)
Willamette Valley	23186 (23.70%)	2936 (22.84%)	4782 (23.70%)	30904 (23.61%)
NA	3 (0.00%)	1 (0.01%)	1 (0.00%)	5 (0.00%)
Total	97837 (100.00%)	12857 (100.00%)	20175 (100.00%)	130869 (100.00%)

3 Modelling Approach

Base Model

The initial analysis plan was to look at quantities of aerators, showerheads and shower wands installed. A review of the quantity of measures provided to the households in the six year analysis period indicated that there was insufficient variance in quantities provided to warrant such an upproach. Only 364, of the more than 19,000 treated homes in the analysis set did not receive an aerator and for those that did receive an aerator the overwhelming majority received either three or four. In the case of showerheads most of the households received either one or two and only very few received more than one shower wand. This led to the following model specification:

$$\text{Base Model} : Savings = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \epsilon$$

where the following applies to both comparison groups:

- $Savings$ = modeled_savings

- X_1 = RecievedSH, which is a dummy variable representing homes which recieved showerheads and is set to zero for the comparison homes
- X_2 = RecievedSW, which is a dummy variable representing homes which recieved shower wands and is set to zero for the comparison homes
- e = residual error

Modified model with interaction terms

A modified version for each of the comparison groups which includes interaction terms with categorical/factor/binary variables for the following site characteristics:

- Installation Period
- House Size (in square feet)
- House vintage (year it was built)
- Gas use (in therms) during baseline period
- Region
- Type of structure (site built vs manufactured home)(After looking at the data this group was deemed insufficient for analysis)
- Census tract average household size
- Census tract median household income

$$\text{Interaction Model : } Savings = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_1 X_2 + \epsilon$$

where

- X_1 is a binary variable for treatment status (received ESK)
- X_2 is one of the site characteristics of interest
- e = residual error

4 Creating New Categorical Variables

For all study groups:

- InstallPeriod = categorical variable for period of installation where:
  - InstallPeriod = 1 if InstalledYear is between 2013 to 2014
  - InstallPeriod = 2 if InstalledYear is between 2015 to 2016
  - InstallPeriod = 3 if InstalledYear is between 2017 to 2018
- HomeSize = categorical variable for square footage where:
  - HomeSize = 1 if SqFt < 1,200
  - HomeSize = 2 if SqFt is between 1,200 to 2,000
  - HomeSize = 3 if SqFt is between 2,000 to 3,000
  - HomeSize = 4 if SqFt > 3,000
- Vintage = categorical variable for the year the site was built where:
  - Vintage = 1 if YearBuilt < 1930
  - Vintage = 2 if YearBuilt is between 1930 to 1960
  - Vintage = 3 if YearBuilt is between 1960 to 1990
  - Vintage = 4 if YearBuilt > 1990
- GasUse = categorical values of annual gas use (therms) in baseline period where:
  - GasUse = 1 if baseline_predicted_usage =< 490
  - GasUse = 2 if baseline_predicted_usage between 490 to 640
  - GasUse = 3 if baseline_predicted_usage between 640 to 810
  - GasUse = 4 if baseline_predicted_usage => 810
- Region = categorical value for region where:
  - RegionCategory = 1 for "Central Oregon" or "Eastern Oregon"
  - RegionCategory = 2 for "Southern Oregon" or "North Coast"
  - RegionCategory = 3 for "Portland Metro & Hood River"
  - RegionCategory = 4 for "Willamette Valley"
  - RegionCategory = 5 for "Southwest Washington"
- Income = Categorical value for Income where:
  - Income = 1 if Median household income in the past 12 months is in the first quintile
  - Income = 2 if Median household income in the past 12 months is in the second quintile
  - Income = 3 if Median household income in the past 12 months is in the third quintile
  - Income = 4 if Median household income in the past 12 months is in the fourth quintile
  - Income = 5 if Median household income in the past 12 months is in the fifth quintile
- HouseholdSize = Categorical value for household size where:
  - HouseholdSize = 1 if Average household size is in the first quintile
  - HouseholdSize = 2 if Average household size is in the second quintile
  - HouseholdSize = 3 if Average household size is in the third quintile
  - HouseholdSize = 4 if Average household size is in the fourth quintile
  - HouseholdSize = 5 if Average household size is in the fifth quintile

New Dummy Variables (Basline for the Analysis):

- ShowerTotalQty = ShowerHeadQty + ShowerheadWandQty
- RecievedSH = dummy variable for whether a home recieved a showerhead and set to:

  - 1 for homes that recieved a showerhead
  - zero for all other homes

- RecievedSW = dummy variable for whether a home recieved a shower wand and set to:
  - 1 for homes that recieved a shower wand
  - zero for all other homes

Data QC

1. Check that all treated sites received at least 1 shower head or wand according to CRM
2. Check for inconsistencies between CRM and Recurve for fuel classification:
   - Create flags for sites that indicated fuel as not GAS in CRM and not likely gas according to Recurve. While these might be appropriate to remove in future analyses, for this report we assume the Recurve classification is accurate.
   - Create flags for sites that indicated fuel as not GAS in CRM but likely gas according to Recurve (there were ~5600 sites). While these might be appropriate to remove in future analyses, for this report we assume the Recurve classification is accurate.
3. Check the number of treated and comparison sites with missing site characteristics that are necessary for the interaction models (SqFt, YearBuilt, etc.) These will be dropped for their respective regression model.
   - Create flags for sites with missing site characteristics
   - Create a column which links all counterfactual sites to their treated site (by site ID) and create flags for missing info based on these counterfactual-treatment groups
     - If a treated site is dropped because of missing info, its counterfactuals can be dropped as well based on these groupings (e.g. where flag_treated_no_sqft==TRUE, or flag_treated_no_yearbuilt==TRUE. etc.)
     - If all counterfactuals for a treated site have no characteristic information, the treated site can also be dropped based on these groupings (e.g. where matched_no_sqft==5, or matched_no_yearbuilt==5, etc.)

Through this Anlysis:

- 104 cases of flag_not_gas==TRUE were found.
- 5671 cases of flag_uncertain_gas==TRUE were found.
- 9652 cases of flag_treated_no_sqft==TRUE were found.
- 9704 cases of flag_treated_no_yearbuilt==TRUE were found.
- 7 cases of flag_treated_no_region==TRUE were found.
- 16334 cases where 5 matched comparison sites had no sqft were found.
- 16425 cases where 5 matched site had not yearbuilt were found.
- 18 cases where 5 matched site had no region info were found.

For Each variables respective regression, these flagged cases will be filtered out.

In addition, there were 481 sites that were repeat participants for the treatment group. Because we assume that the replacing an efficient showerhead with another efficient showerhead will not lead to additional savings, the later year repeat participants must be removed, as well as their matched participant group. In doing so, 481 repeat participants were removed as well as 2878 matched homes.

4.0.1 Summary statistics of final dataset to be used in analysis

The following tables are based on the modeled_savings field

Table 11: Number of Sites in Each Study Group Within Final Analysis Sample

Site Type	n	Percent
individual_matched	95,440	75.97%
stratified_future_participants	10,546	8.39%
treatment	19,648	15.64%
Total	125,634	100.00%

Table 12: Weather Normalized Savings (therms) By Whether Home Recieved SH

Group	InstalledSH	N	mean	max	min	sum	sd
individual_matched	0	95,440	-9.97	1,070.89	-887.38	-951,320.83	83.31
stratified_future_participants	0	10,546	-5.23	925.41	-868.73	-55,160.56	96.91
treatment	0	472	4.56	507.16	-631.12	2,154.56	121.02
treatment	1	19,176	-8.97	1,202.46	-1,085.09	-171,999.63	105.80

Table 13: Weather Normalized Savings (therms) By Whether Home Recieved SW

Group	InstalledSW	N	mean	max	min	sum	sd
individual_matched	0	95,440	-9.97	1,070.89	-887.38	-951,320.83	83.31
stratified_future_participants	0	10,546	-5.23	925.41	-868.73	-55,160.56	96.91
treatment	0	18,230	-10.04	1,202.46	-1,085.09	-183,115.67	105.41
treatment	1	1,418	9.36	731.97	-631.12	13,270.60	114.46

Modeled Saving

Table 14: Weather Normalized Savings (therms) By Install Period and Group

portfolio_type	InstallPeriod	N	Mean	Max	Min	Sum	StdDev
individual_matched	2013-2014	48,368	-8.82	993.66	-887.38	-426,751.50	79.90
individual_matched	2015-2016	33,331	-15.39	1,070.89	-809.13	-513,027.10	88.04
individual_matched	2017-2018	13,741	-0.84	878.22	-819.99	-11,542.23	82.30
stratified_future_participants	2013-2014	5,638	-2.04	925.41	-611.98	-11,490.91	95.97
stratified_future_participants	2015-2016	4,416	-8.87	782.59	-868.73	-39,180.58	97.17
stratified_future_participants	2017-2018	492	-9.12	571.59	-384.32	-4,489.07	103.92
treatment	2013-2014	10,075	-7.44	1,202.46	-1,072.29	-74,922.53	100.38
treatment	2015-2016	6,808	-16.18	891.78	-1,085.09	-110,143.94	112.22
treatment	2017-2018	2,765	5.51	731.97	-631.12	15,221.40	110.01

Table 15: Weather Normalized Savings (therms) By HomeSize and Group

portfolio_type	HomeSize	N	Mean	Max	Min	Sum	StdDev
individual_matched	<1200	3,851	-3.45	548.14	-635.56	-13,304.33	72.19
individual_matched	1,200-2,000	17,902	-7.33	1,058.57	-710.32	-131,135.36	78.10
individual_matched	2,000-3,000	9,904	-13.24	878.22	-819.99	-131,169.28	88.67
individual_matched	>3,000	2,633	-18.58	718.99	-760.08	-48,919.80	102.92
individual_matched	NA	61,150	-10.25	1,070.89	-887.38	-626,792.05	83.54
stratified_future_participants	<1200	910	-3.33	486.30	-403.05	-3,028.81	79.86
stratified_future_participants	1,200-2,000	4,799	-4.41	782.59	-611.98	-21,170.81	89.92
stratified_future_participants	2,000-3,000	2,682	-4.99	925.41	-868.73	-13,377.06	102.50
stratified_future_participants	>3,000	819	-4.80	724.72	-542.09	-3,928.34	131.64
stratified_future_participants	NA	1,336	-10.22	433.14	-475.39	-13,655.54	95.01
treatment	<1200	1,881	-1.41	1,202.46	-696.94	-2,660.86	95.59
treatment	1,200-2,000	9,653	-6.70	1,025.37	-667.66	-64,641.75	98.42
treatment	2,000-3,000	5,232	-12.85	731.97	-1,085.09	-67,251.40	112.41
treatment	>3,000	1,525	-19.40	789.05	-1,072.29	-29,590.97	135.20
treatment	NA	1,357	-4.20	732.35	-536.67	-5,700.09	110.54

Table 16: Weather Normalized Savings (therms) By House Vintage and Group

Group	Vintage	N	mean	max	min	sum	sd
individual_matched	<1930	3,938	-8.87	781.98	-809.13	-34,935.21	83.18
individual_matched	1930-1960	5,205	-7.24	875.78	-819.99	-37,695.21	90.70
individual_matched	1960-1990	12,029	-8.95	1,058.57	-810.79	-107,699.23	87.03
individual_matched	>1990	13,092	-11.05	878.22	-715.72	-144,722.77	75.13
individual_matched	NA	61,176	-10.24	1,070.89	-887.38	-626,268.40	83.57
stratified_future_participants	<1930	941	-3.21	592.04	-473.84	-3,021.97	99.13
stratified_future_participants	1930-1960	1,271	-0.24	925.41	-446.70	-305.97	105.34
stratified_future_participants	1960-1990	2,990	-2.77	749.23	-868.73	-8,283.89	101.90
stratified_future_participants	>1990	4,005	-7.40	769.11	-496.91	-29,637.44	90.24
stratified_future_participants	NA	1,339	-10.39	433.14	-475.39	-13,911.28	94.50
treatment	<1930	1,813	-5.87	789.05	-797.60	-10,641.58	113.21
treatment	1930-1960	2,467	-6.25	1,202.46	-883.80	-15,417.45	115.37
treatment	1960-1990	5,796	-8.35	891.78	-1,085.09	-48,389.96	112.48
treatment	>1990	8,208	-11.14	1,025.37	-1,072.29	-91,400.78	95.64
treatment	NA	1,364	-2.93	732.35	-536.67	-3,995.29	111.91

Table 17: Weather Normalized Savings (therms) By Baseline Gas Use and Group

Group	Vintage	N	mean	max	min	sum	sd
individual_matched	<490	23,537	-14.84	403.64	-443.32	-349,320.23	61.67
individual_matched	490-640	24,652	-13.50	493.16	-554.90	-332,908.93	71.10
individual_matched	640-810	23,743	-8.65	692.07	-759.34	-205,479.03	83.08
individual_matched	>810	23,508	-2.71	1,070.89	-887.38	-63,612.63	109.56
stratified_future_participants	<490	2,676	-21.04	358.67	-475.39	-56,304.10	73.14
stratified_future_participants	490-640	2,782	-12.92	498.59	-547.80	-35,936.19	80.39
stratified_future_participants	640-810	2,580	-2.94	646.74	-611.98	-7,592.33	92.95
stratified_future_participants	>810	2,508	17.81	925.41	-868.73	44,672.06	129.88
treatment	<490	4,864	-22.96	389.28	-422.81	-111,657.18	78.21
treatment	490-640	5,056	-15.62	613.31	-536.67	-78,961.53	88.90
treatment	640-810	4,821	-6.72	732.50	-672.53	-32,388.76	100.33
treatment	>810	4,907	10.83	1,202.46	-1,085.09	53,162.40	142.98

Table 18: Weather Normalized Savings (therms) By Region and Group

Group	Region	N	mean	max	min	sum	sd
individual_matched	1	3,211	-15.59	673.83	-430.32	-50,057.01	90.87
individual_matched	2	3,138	-5.82	835.84	-809.13	-18,267.44	97.22
individual_matched	3	64,193	-10.73	1,058.57	-887.38	-688,513.17	83.40
individual_matched	4	22,556	-7.57	1,070.89	-759.34	-170,794.34	79.92
individual_matched	5	2,339	-10.08	783.91	-587.96	-23,584.28	80.76
individual_matched	NA	3	-34.86	45.72	-106.71	-104.59	76.59
stratified_future_participants	1	289	-11.06	521.13	-429.50	-3,195.82	94.33
stratified_future_participants	2	291	-1.59	418.17	-384.32	-462.19	94.38
stratified_future_participants	3	7,239	-5.21	925.41	-868.73	-37,749.39	97.41
stratified_future_participants	4	2,473	-4.71	782.59	-611.98	-11,641.37	94.86
stratified_future_participants	5	253	-7.92	769.11	-251.64	-2,004.45	107.86
stratified_future_participants	NA	1	-107.33	-107.33	-107.33	-107.33	NaN
treatment	1	658	-16.20	789.05	-741.47	-10,656.40	109.70
treatment	2	634	-10.09	671.21	-691.38	-6,396.45	111.91
treatment	3	13,231	-8.68	1,202.46	-1,085.09	-114,869.27	107.47
treatment	4	4,652	-7.99	732.50	-750.82	-37,187.87	101.82
treatment	5	472	-1.45	448.30	-412.19	-684.75	99.79
treatment	NA	1	-50.33	-50.33	-50.33	-50.33	NaN

Table 19: Weather Normalized Savings (therms) By Income and Group

Group	Income	N	mean	max	min	sum	sd
individual_matched	1	18,602	-6.25	1,070.89	-809.13	-116,251.75	83.34
individual_matched	2	18,765	-7.30	856.52	-887.38	-136,922.29	82.33
individual_matched	3	18,493	-10.95	1,058.57	-663.10	-202,463.05	82.18
individual_matched	4	18,797	-11.32	822.31	-715.72	-212,809.29	81.52
individual_matched	5	18,439	-14.05	878.22	-819.99	-259,155.77	87.19
individual_matched	NA	2,344	-10.12	783.91	-587.96	-23,718.66	80.71
stratified_future_participants	1	1,998	-7.14	646.74	-475.39	-14,264.81	93.69
stratified_future_participants	2	2,005	-5.40	782.59	-868.73	-10,826.30	95.95
stratified_future_participants	3	2,125	-3.68	601.48	-611.98	-7,820.16	89.59
stratified_future_participants	4	2,084	-8.81	925.41	-542.09	-18,360.12	99.78
stratified_future_participants	5	2,080	-0.85	749.23	-524.27	-1,777.38	103.44
stratified_future_participants	NA	254	-8.31	769.11	-251.64	-2,111.79	107.83
treatment	1	3,853	-8.26	789.05	-741.47	-31,831.09	104.76
treatment	2	3,746	-7.38	693.88	-691.38	-27,646.65	98.37
treatment	3	3,896	-8.68	1,202.46	-696.94	-33,816.94	105.76
treatment	4	3,930	-6.14	732.50	-673.55	-24,115.72	103.72
treatment	5	3,750	-13.79	891.78	-1,085.09	-51,699.60	118.27
treatment	NA	473	-1.55	448.30	-412.19	-735.07	99.71

Table 20: Weather Normalized Savings (therms) By Household Size and Group

Group	HouseholdSize	N	mean	max	min	sum	sd
individual_matched	1	19,454	-7.92	993.66	-809.13	-154,029.13	86.89
individual_matched	2	19,830	-11.16	866.07	-887.38	-221,401.26	85.71
individual_matched	3	18,345	-10.10	875.78	-807.56	-185,350.13	81.29
individual_matched	4	17,232	-11.12	794.53	-819.99	-191,569.70	80.33
individual_matched	5	18,235	-9.61	1,070.89	-663.10	-175,251.94	81.78
individual_matched	NA	2,344	-10.12	783.91	-587.96	-23,718.66	80.71
stratified_future_participants	1	2,138	-5.04	702.23	-547.80	-10,765.88	95.36
stratified_future_participants	2	2,237	-2.63	925.41	-868.73	-5,886.04	100.40
stratified_future_participants	3	1,972	0.23	749.23	-611.98	448.18	98.62
stratified_future_participants	4	1,876	-8.40	724.72	-524.27	-15,754.62	93.95
stratified_future_participants	5	2,069	-10.19	782.59	-542.09	-21,090.42	93.94
stratified_future_participants	NA	254	-8.31	769.11	-251.64	-2,111.79	107.83
treatment	1	3,960	-9.90	731.97	-1,085.09	-39,213.85	106.99
treatment	2	4,089	-8.54	891.78	-1,072.29	-34,921.58	109.53
treatment	3	3,727	-7.55	1,202.46	-559.05	-28,121.40	103.32
treatment	4	3,630	-8.04	720.03	-797.60	-29,174.49	104.36
treatment	5	3,769	-10.00	1,025.37	-857.12	-37,678.67	107.11
treatment	NA	473	-1.55	448.30	-412.19	-735.07	99.71

5 Regression Results

5.1 Overall Results

$$\widehat{Savings} = \hat{\beta}_0 + \hat{\beta}_1 X_1 + \hat{\beta}_2 X_2 + \epsilon$$

For the both groups comparison group:

- $Savings$ = modeled_savings
- X_1 = RecievedSH, which is a dummy variable representing homes which recieved showerheads and is set to zero for the comparison homes
- X_2 = RecievedSW, which is a dummy variable representing homes which recieved shower wands and is set to zero for the comparison homes
- e = residual error

Table 21: Overall Regression Results for Matched Control and Future Participant Comparison Groups

	Dependent variable:	
	modeled_savings	
	Matched Comparison Group	Stratified Future Participants
	(1)	(2)
RecievedSH	0.069 (−1.084, 1.222)	−4.274*** (−6.299, −2.249)
RecievedSW	19.304*** (15.409, 23.199)	17.783*** (13.174, 22.391)
Constant	−9.991*** (−10.457, −9.525)	−5.573*** (−7.198, −3.947)
Observations	115,088	30,194
R^2	0.001	0.002
Adjusted R^2	0.001	0.002
Residual Std. Error	87.616 (df = 115085)	102.982 (df = 30191)
F Statistic	34.120*** (df = 2; 115085)	25.849*** (df = 2; 30191)
Note:		*p<0.1; **p<0.05; ***p<0.01

The values in the bracket represent the 90% confidence interval levels

The regression results indicate that there is no reduction in consumption for households receiving a showerhead. The installation of a shower wand is associated with an additional 18 to 19 therm reduction. It is worth noting that the majority of shower wands were installed in the 2017-2018 installation period.

Using this specification we interact these dummy variables with further variables to determine if geography, installation period, building square footage , or level of gas consumption might help explain the results. In particular, the lack of savings for homes that received showerheads.

5.2 Results by Installation Period

Table 22: Results By Install Period for Matched Control and Future Participant Comparison Groups

	Dependent variable:	
	modeled_savings	
	(1)	(2)
RecievedSH	1.017 (−0.564, 2.598)	−5.907*** (−8.715, −3.099)
RecievedSW	17.969** (5.130, 30.808)	13.991 (−1.153, 29.136)
InstallPeriod2015-2016	−6.586*** (−7.610, −5.562)	−6.952*** (−10.348, −3.557)
InstallPeriod2017-2018	7.782*** (6.400, 9.164)	−7.988** (−14.666, −1.310)
RecievedSH:InstallPeriod2015-2016	−1.786 (−4.268, 0.697)	−1.440 (−5.750, 2.869)
RecievedSH:InstallPeriod2017-2018	3.396 (−0.525, 7.317)	17.758*** (10.525, 24.992)
RecievedSW:InstallPeriod2015-2016	−183.461*** (−267.526, −99.397)	−183.870*** (−282.733, −85.006)
RecievedSW:InstallPeriod2017-2018	−10.228 (−23.895, 3.440)	−2.566 (−18.884, 13.751)
Constant	−8.797*** (−9.451, −8.143)	−1.851 (−4.098, 0.396)
Observations	115,088	30,194
R^2	0.004	0.004
Adjusted R^2	0.004	0.004
Residual Std. Error	87.478 (df = 115079)	102.858 (df = 30185)
F Statistic	54.801*** (df = 8; 115079)	16.368*** (df = 8; 30185)
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 23: Simplified Results by Install Period for Matched Control and Future Participant Comparison Groups

	Individual Matched	tratified Future Participants
RecievedSH_2013_2014	1.02	-5.91
RecievedSH_2015_2016	-0.77	-7.35
RecievedSH_2017_2018	4.41	11.85
RecievedSW_2013_2014	17.97	13.99
RecievedSW_2015_2016	-165.49	-169.88
RecievedSW_2017_2018	7.74	11.42

The regression estimating showerhead, aerator and shower wand savings by period installed indicates that savings for showerheads are more pronounced in the most recent time period, 2017-2018.The savings for a showerhead was estimated to range between 4-11 therms. Shower wands were estimated to add an additional 7-11 therm savings in the 2017-2018 program years. The negative coefficients estimated for shower wands in 2016-2016 might be due to the few households receiving shower wands in these programs years.

5.3 Results by Home Size

Table 24: Results By Home Size for Matched Control and Future Participant Comparison Groups

	Dependent variable:	
	modeled_savings	
	(1)	(2)
RecievedSH	2.420 (−2.151, 6.990)	2.095 (−5.329, 9.520)
RecievedSW	29.462*** (13.338, 45.586)	29.244*** (10.611, 47.877)
HomeSize1,200-2,000	−3.233* (−5.995, −0.470)	−0.509 (−7.121, 6.102)
HomeSize2,000-3,000	−9.273*** (−12.228, −6.317)	−1.662 (−8.665, 5.341)
HomeSize>3,000	−15.169*** (−19.131, −11.207)	1.644 (−7.156, 10.445)
RecievedSH:HomeSize1,200-2,000	−3.581 (−8.580, 1.418)	−6.261 (−14.332, 1.810)
RecievedSH:HomeSize2,000-3,000	−3.218 (−8.552, 2.116)	−10.734** (−19.304, −2.165)
RecievedSH:HomeSize>3,000	−2.148 (−9.055, 4.759)	−18.766*** (−29.593, −7.939)
RecievedSW:HomeSize1,200-2,000	−12.834 (−30.192, 4.525)	−13.661 (−33.685, 6.362)
RecievedSW:HomeSize2,000-3,000	−6.778 (−25.284, 11.727)	−8.682 (−29.987, 12.623)
RecievedSW:HomeSize>3,000	−27.686* (−52.474, −2.898)	−33.663* (−62.068, −5.257)
Constant	−4.075*** (−6.585, −1.566)	−3.747 (−9.838, 2.344)
Observations	47,800	24,009
R^2	0.003	0.003
Adjusted R^2	0.003	0.003
Residual Std. Error	91.159 (df = 47788)	103.390 (df = 23997)
F Statistic	13.641*** (df = 11; 47788)	7.011*** (df = 11; 23997)
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 25: Simplified Results by Home Size for Matched Control and Future Participant Comparison Groups

	Individual Matched	Stratified Future Participants
RecievedSH:HomeSize400-1200	2.42	2.10
RecievedSH:HomeSize1,200-2,000	-1.16	-4.17
RecievedSH:HomeSize2,000-3,000	-0.80	-8.64
RecievedSH:HomeSize>3,000	0.27	-16.67
RecievedSW:HomeSize400-1200	29.46	29.24
RecievedSW:HomeSize1,200-2,000	16.63	15.58
RecievedSW:HomeSize2,000-3,000	22.68	20.56
RecievedSW:HomeSize>3,000	1.78	-4.42

The regression estimating showerhead, aerator, and shower wand savings by building square footage indicates that the smaller homes were associated with higher savings. Those savings were most pronounced in smaller buildings (400-1200) sqft, where the savings were estimated at 29 therms for shower wands and 2 therms for showerheads. Both showerheads and shower wands saw the lowest savings in homes larger than 3000 feet. Overall, it looks like there are more savings associated with shower wands across the board.

5.4 Results by House Vintage

Table 26: Results By House Vintage for Matched Control and Future Participant Comparison Groups

	Dependent variable:	
	modeled_savings	
	(1)	(2)
RecievedSH	3.457 (−1.011, 7.926)	−3.094 (−10.165, 3.977)
RecievedSW	10.313 (−5.548, 26.175)	6.835 (−11.346, 25.015)
Vintage1930-1960	1.795 (−1.444, 5.034)	1.929 (−5.615, 9.473)
Vintage1960-1990	0.740 (−2.079, 3.558)	0.398 (−6.170, 6.966)
Vintage>1990	−1.707 (−4.500, 1.086)	−4.910 (−11.311, 1.491)
RecievedSH:Vintage1930-1960	−2.602 (−8.519, 3.315)	−2.717 (−12.051, 6.617)
RecievedSH:Vintage1960-1990	−5.468* (−10.617, −0.319)	−5.113 (−13.240, 3.014)
RecievedSH:Vintage>1990	−5.001 (−10.016, 0.015)	−1.855 (−9.758, 6.048)
RecievedSW:Vintage1930-1960	1.951 (−18.353, 22.256)	1.866 (−21.422, 25.154)
RecievedSW:Vintage1960-1990	8.664 (−9.061, 26.389)	9.919 (−10.380, 30.217)
RecievedSW:Vintage>1990	11.548 (−6.061, 29.156)	14.185 (−5.968, 34.337)
Constant	−9.451*** (−11.892, −7.010)	−2.805 (−8.522, 2.912)
Observations	47,939	24,071
R^2	0.001	0.002
Adjusted R^2	0.001	0.002
Residual Std. Error	91.080 (df = 47927)	103.309 (df = 24059)
F Statistic	5.262*** (df = 11; 47927)	5.293*** (df = 11; 24059)
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 27: Simplified Results by Vintage for Matched Control and Future Participant Comparison Groups

	Individual Matched	Stratified Future Participants
RecievedSH:Vintage<1930	3.46	-3.09
RecievedSH:Vintage1930-1960	0.86	-5.81
RecievedSH:Vintage1960-1990	-2.01	-8.21
RecievedSH:Vintage>1990	-1.54	-4.95
RecievedSW:Vintage<1930	10.31	6.83
RecievedSW:Vintage1930-1960	12.26	8.70
RecievedSW:Vintage1960-1990	18.98	16.75
RecievedSW:Vintage>1990	21.86	21.02

The regression estimating showerhead, aerator, and shower wand savings by house vintage shows the trend that savings for shower wands installed increase as the house gets newer.

5.5 Results by Gas Use

Table 28: Results By House Gas Use for Matched Control and Future Participant Comparison Groups

	Dependent variable:	
	modeled_savings	
	(1)	(2)
RecievedSH	-8.392^{***} (-10.697, -6.088)	-2.037 (-6.047, 1.972)
RecievedSW	6.488 (-1.849, 14.824)	8.764 (-1.039, 18.568)
GasUse490-640	1.395^{*} (0.088, 2.702)	8.452^{***} (3.964, 12.940)
GasUse640-810	6.238^{***} (4.919, 7.558)	18.210^{***} (13.640, 22.780)
GasUse>810	12.164^{***} (10.842, 13.487)	38.285^{***} (33.684, 42.886)
RecievedSH:GasUse490-640	5.314^{***} (2.085, 8.543)	-1.637 (-7.249, 3.976)
RecievedSH:GasUse640-810	9.759^{***} (6.486, 13.032)	-2.017 (-7.722, 3.688)
RecievedSH:GasUse>810	18.925^{***} (15.664, 22.186)	-6.742^{*} (-12.460, -1.024)
RecievedSW:GasUse490-640	6.253 (-5.222, 17.729)	3.747 (-9.757, 17.251)
RecievedSW:GasUse640-810	1.227 (-9.971, 12.425)	-2.811 (-15.982, 10.359)
RecievedSW:GasUse>810	37.003^{***} (25.810, 48.196)	28.199^{***} (15.030, 41.368)
Constant	-14.895^{***} (-15.830, -13.960)	-21.346^{***} (-24.552, -18.139)
Observations	115,088	30,194
R^2	0.007	0.019
Adjusted R^2	0.007	0.018
Residual Std. Error	87.348 (df = 115076)	102.113 (df = 30182)
F Statistic	71.326^{***} (df = 11; 115076)	52.503^{***} (df = 11; 30182)
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 29: Simplified Results by Gas Use for Matched Control and Future Participant Comparison Groups

	Individual Matched	Stratified Future Participants
RecievedSH:GasUse<=490	-8.39	-2.04
RecievedSH:GasUse490-640	-3.08	-3.67
RecievedSH:GasUse640-810	1.37	-4.05
RecievedSH:GasUse>810	10.53	-8.78
RecievedSWGasUse<=490	6.49	8.76
RecievedSW:GasUse490-640	12.74	12.51
RecievedSW:GasUse640-810	7.71	5.95
RecievedSW:GasUse>810	43.49	36.96

The regression estimating showerhead aerator and shower wand savings by gas use indicates that savings for participants are related to gas use. For showerheads it appears savings increase as gas use rises. It is important to note that this trend is only apparent for the matched participants regression. This could be because of the smaller sample size of future participants. Shower wands consistanly had positive savings across all gas usage, with the highest savings being at the highest gas usage.

5.6 Results by Region

- Region = categorical value for region where:
  - RegionCategory = 1 for "Central Oregon" or "Eastern Oregon"
  - RegionCategory = 2 for "Southern Oregon" or "North Coast"
  - RegionCategory = 3 for "Portland Metro & Hood River"
  - RegionCategory = 4 for "Willamette Valley"
  - RegionCategory = 5 for "Southwest Washington"

Table 30: Results By Region for Matched Control and Future Participant Comparison Groups

	Dependent variable:	
	modeled_savings	
	(1)	(2)
RecievedSH	−3.028 (−9.249, 3.192)	−7.289 (−19.153, 4.575)
RecievedSW	77.743*** (46.091, 109.394)	76.086*** (38.705, 113.468)
RegionCategory2	9.634*** (6.025, 13.244)	7.930 (−5.849, 21.710)
RegionCategory3	4.822*** (2.219, 7.425)	5.460 (−4.612, 15.532)
RegionCategory4	8.088*** (5.373, 10.803)	7.116 (−3.316, 17.548)
RegionCategory5	5.602** (1.696, 9.507)	3.913 (−10.316, 18.142)
RecievedSH:RegionCategory2	−5.460 (−14.509, 3.590)	−3.694 (−20.357, 12.969)
RecievedSH:RegionCategory3	3.979 (−2.396, 10.355)	3.382 (−8.734, 15.497)
RecievedSH:RegionCategory4	1.338 (−5.320, 7.997)	2.338 (−10.238, 14.914)
RecievedSH:RegionCategory5	14.602** (4.535, 24.668)	16.406 (−1.192, 34.005)
RecievedSW:RegionCategory2	−46.302** (−81.494, −11.111)	−45.529* (−87.170, −3.888)
RecievedSW:RegionCategory3	−54.266*** (−86.328, −22.205)	−54.394** (−92.260, −16.527)
RecievedSW:RegionCategory4	−67.084*** (−99.650, −34.518)	−66.525*** (−104.990, −28.060)
RecievedSW:RegionCategory5	−88.838*** (−123.677, −53.999)	−87.950*** (−129.160, −46.740)
Constant	−15.605*** (−18.146, −13.065)	−11.312* (−21.190, −1.433)
Observations	115,079	30,192
R^2	0.001	0.003
Adjusted R^2	0.001	0.002
Residual Std. Error	87.592 (df = 115064)	102.959 (df = 30177)
F Statistic	10.443*** (df = 14; 115064)	5.599*** (df = 14; 30177)
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 31: Simplified Results by Region for Matched Control and Future Participant Comparison Groups

	Individual Matched	Stratified Future Participants
RecievedSH:RegionCategory1	-3.03	-7.29
RecievedSH:RegionCategory2	-8.49	-10.98
RecievedSH:RegionCategory3	0.95	-3.91
RecievedSH:RegionCategory4	-1.69	-4.95
RecievedSH:RegionCategory5	11.57	9.12
RecievedSW:RegionCategory1	77.74	76.09
RecievedSW:RegionCategory2	31.44	30.56
RecievedSW:RegionCategory3	23.48	21.69
RecievedSW:RegionCategory4	10.66	9.56
RecievedSW:RegionCategory5	-11.10	-11.86

The regression estimating showerhead aerator and shower wand savings by region indicates that showerheads see the most savings in region 5, Southwest Washington. The shower wand variable sees the most savings in region 1, Central or Eastern Oregon.

5.7 Results by Income

Table 32: Results By Income for Matched Control and Future Participant Comparison Groups

	Dependent variable:	
	modeled_savings	
	(1)	(2)
RecievedSH	−3.653** (−6.266, −1.039)	−2.423 (−7.025, 2.180)
RecievedSW	21.357*** (13.233, 29.481)	21.882*** (12.227, 31.537)
Income2	−0.979 (−2.468, 0.510)	2.270 (−2.994, 7.534)
Income3	−4.701*** (−6.196, −3.206)	3.266 (−1.931, 8.464)
Income4	−4.993*** (−6.481, −3.505)	−1.066 (−6.283, 4.151)
Income5	−7.840*** (−9.336, −6.344)	5.705* (0.476, 10.934)
RecievedSH:Income2	2.530 (−1.184, 6.244)	−0.656 (−7.192, 5.880)
RecievedSH:Income3	5.302** (1.626, 8.977)	−2.548 (−9.009, 3.912)
RecievedSH:Income4	6.374*** (2.701, 10.047)	2.516 (−3.955, 8.987)
RecievedSH:Income5	3.327 (−0.376, 7.029)	−10.048** (−16.557, −3.539)
RecievedSW:Income2	−9.391 (−21.330, 2.549)	−10.582 (−24.732, 3.568)
RecievedSW:Income3	−4.962 (−17.636, 7.712)	−7.745 (−22.749, 7.259)
RecievedSW:Income4	12.546* (0.508, 24.584)	11.161 (−3.099, 25.420)
RecievedSW:Income5	−0.377 (−13.623, 12.869)	−4.845 (−20.512, 10.823)
Constant	−6.299*** (−7.354, −5.244)	−7.557*** (−11.275, −3.839)
Observations	112,271	29,467
R^2	0.002	0.003
Adjusted R^2	0.002	0.002
Residual Std. Error	87.654 (df = 112256)	102.963 (df = 29452)
F Statistic	14.034*** (df = 14; 112256)	5.722*** (df = 14; 29452)
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 33: Simplified Results by Income for Matched Control and Future Participant Comparison Groups

	Individual Matched	Stratified Future Participants
RecievedSH:Income1	-3.65	-2.42
RecievedSH:Income2	-1.12	-3.08
RecievedSH:Income3	1.65	-4.97
RecievedSH:Income4	2.72	0.09
RecievedSH:Income5	-0.33	-12.47
RecievedSW:Income1	21.36	21.88
RecievedSW:Income2	11.97	11.30
RecievedSW:Income3	16.39	14.14
RecievedSW:Income4	33.90	33.04
RecievedSW:Income5	20.98	17.04

There are no clear trends revealed when including income variables into the model.

5.8 Results by Household Size

Table 34: Results By Household Size for Matched Control and Future Participant Comparison Groups

	Dependent variable:	
	modeled_savings	
	(1)	(2)
RecievedSH	−2.873* (−5.439, −0.307)	−4.603* (−9.096, −0.110)
RecievedSW	21.774*** (13.138, 30.411)	21.024*** (10.781, 31.268)
HouseholdSize2	−3.151*** (−4.605, −1.698)	3.102 (−1.943, 8.147)
HouseholdSize3	−2.026** (−3.508, −0.544)	6.551** (1.333, 11.770)
HouseholdSize4	−3.081*** (−4.588, −1.575)	−2.297 (−7.581, 2.987)
HouseholdSize5	−1.543* (−3.028, −0.059)	−3.731 (−8.878, 1.416)
RecievedSH:HouseholdSize2	4.182* (0.580, 7.783)	−1.963 (−8.257, 4.331)
RecievedSH:HouseholdSize3	4.601** (0.920, 8.282)	−3.880 (−10.372, 2.612)
RecievedSH:HouseholdSize4	4.669** (0.959, 8.380)	3.887 (−2.670, 10.443)
RecievedSH:HouseholdSize5	0.280 (−3.403, 3.963)	2.428 (−4.001, 8.857)
RecievedSW:HouseholdSize2	0.431 (−11.786, 12.649)	−2.005 (−16.484, 12.473)
RecievedSW:HouseholdSize3	−10.211 (−23.306, 2.884)	−12.396 (−27.873, 3.081)
RecievedSW:HouseholdSize4	1.556 (−11.611, 14.722)	1.460 (−14.114, 17.035)
RecievedSW:HouseholdSize5	4.854 (−7.381, 17.089)	5.730 (−8.745, 20.205)
Constant	−8.049*** (−9.081, −7.017)	−6.286*** (−9.892, −2.680)
Observations	112,271	29,467
R^2	0.001	0.003
Adjusted R^2	0.001	0.002
Residual Std. Error	87.692 (df = 112256)	102.968 (df = 29452)
F Statistic	7.136*** (df = 14; 112256)	5.533*** (df = 14; 29452)
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 35: Simplified Results by Household Size for Matched Control and Future Participant Comparison Groups

	Individual Matched	Stratified Future Participants
RecievedSH:HouseholdSize1	-2.87	-4.60
RecievedSH:HouseholdSize2	1.31	-6.57
RecievedSH:HouseholdSize3	1.73	-8.48
RecievedSH:HouseholdSize4	1.80	-0.72
RecievedSH:HouseholdSize5	-2.59	-2.18
RecievedSW:HouseholdSize1	21.77	21.02
RecievedSW:HouseholdSize2	22.21	19.02
RecievedSW:HouseholdSize3	11.56	8.63
RecievedSW:HouseholdSize4	23.33	22.48
RecievedSW:HouseholdSize5	26.63	26.75

When including the mean household size for each census tract, no trend in energy savings is revealed.

5.9 Final Results

After reviewing the results for the subgroup of analyses, there two results stand out: Shower wands perform better than showerheads and showerheads have greater estimated savings in the most recent period; 2017-2018 These two results are intertwined because shower wands were primarily (>90%) sent out during the 2017-2018 time period. To focus on these two specific findings three additional regressions run and the program savings estimated for each. The regressions are run separately for each of the two-year time periods. The only explanatory variable for the 2013-2014 and 2015-2016 periods is a participation variable that provides an estimate of gas savings from the showerhead and aerators received. The regression for the 2017-2018 period also includes the additional variable shower wand to estimate the additional savings associated with receiving one or more shower wand. The savings generated by one installed showerhead and shower wand are calculated by adjusting the regression savings by the average number of showerheads and shower wands received by participating households, as well as the installation rates of showerheads and shower wands.

Table 36: Average Number of Showerheads and Shower Wands Received and their Installation Rates by Program Period

InstallPeriod	Installation_Rate	AverageSHRecieved	N
2013-2014	0.62	1.78	10,003
2015-2016	0.49	1.81	6,806
2017-2018	0.55	1.51	2,367
InstallPeriod	Installation_Rate	AverageSWRecieved	N
2013-2014	0.62	1.34	126
2015-2016	0.49	1.00	3
2017-2018	0.55	1.00	1,289

5.10 The 2013-2014 and 2015-2016 Program Period

As the 2013-2014 and 2015-2016 program periods had so few shower wands delivered the two models focus on participation, I.e. receiving either a showerhead or shower wand. That model is shown below:

$$\text{Base Model} : Savings = \beta_0 + \beta_1 X_1 + \epsilon$$

where the following applies to both comparison groups:

- $Savings$ = modeled_savings
- X_1 = Participate, which is a dummy variable representing portfolio_type = treatment
- e = residual error

Table 37: 2013-2014 Regression Results for Matched Control and Future Participant Comparison Groups

	Dependent variable:	
	modeled_savings	
	Matched Comparison Group	Stratified Future Participants
	(1)	(2)
Participate	1.387 (−0.123, 2.896)	−5.398*** (−8.102, −2.695)
Constant	−8.823*** (−9.450, −8.196)	−2.038 (−4.203, 0.127)
Observations	58,443	15,713
R^2	0.00004	0.001
Adjusted R^2	0.00002	0.001
Residual Std. Error	83.786 (df = 58441)	98.819 (df = 15711)
F Statistic	2.283 (df = 1; 58441)	10.788*** (df = 1; 15711)
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 38: 2015-2016 Regression Results for Matched Control and Future Participant Comparison Groups

	Dependent variable:	
	modeled_savings	
	Matched Comparison Group	Stratified Future Participants
	(1)	(2)
Participate	−0.787 (−2.812, 1.239)	−5.398*** (−8.102, −2.695)
Constant	−15.392*** (−16.226, −14.558)	−2.038 (−4.203, 0.127)
Observations	40,139	15,713
R^2	0.00001	0.001
Adjusted R^2	−0.00001	0.001
Residual Std. Error	92.583 (df = 40137)	98.819 (df = 15711)
F Statistic	0.408 (df = 1; 40137)	10.788*** (df = 1; 15711)
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 39: Therm Savings Estimates for a Single Installed Showerhead and Shower Wand for the 2013-2014 and 2015-2016 Program Periods Using the Matched Control and Future Participant Comparison Groups

	Individual Matched	Stratified Future Participants
Participated 2013-14	1.24	-4.82
	Individual Matched	Stratified Future Participants
Participated 2015-16	-0.89	-6.1

The models for each of the two program periods indicate that the showerheads, shower wands and aerators that were delivered during the four-year period did not result in gas savings. The estimated regression coefficients are either negative (3 of the 4) or positive but not significantly different from zero. The installed showerhead savings calculated from these regressions results in negligible to zero savings.

5.11 2017-2018 Program Period

The 2017-2018 regression model splits out the showerhead and shower wand as over 90% of the shower wands were delivered during this period. The model is specified as:

$$\text{Base Model} : Savings = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \epsilon$$

where the following applies to both comparison groups:

- $Savings$ = modeled_savings
- X_1 = RecievedSH, which is a dummy variable representing homes which recieved showerheads and is set to zero for the comparison homes
- X_2 = RecievedSW, which is a dummy variable representing homes which recieved shower wands and is set to zero for the comparison homes.
- e = residual error

Table 40: 2017-2018 Overall Regression Results for Matched Control and Future Participant Comparison Groups

	Dependent variable:	
	modeled_savings	
	Matched Comparison Group	Stratified Future Participants
	(1)	(2)
RecievedSH	4.413** (0.822, 8.004)	11.851*** (4.787, 18.916)
RecievedSW	7.742*** (3.052, 12.432)	11.425*** (4.987, 17.862)
Constant	−1.015 (−2.233, 0.204)	−9.839** (−16.503, −3.175)
Observations	16,506	3,257
R^2	0.001	0.005
Adjusted R^2	0.001	0.004
Residual Std. Error	87.535 (df = 16503)	109.000 (df = 3254)
F Statistic	10.373*** (df = 2; 16503)	7.580*** (df = 2; 3254)
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 41: Results for Showerhead and Shower Wand Installed for Matched Control and Future Participant Comparison Groups

	Individual Matched	Stratified Future Participants
InstallSH	5.32	14.29
InstallSW	14.08	20.77

The results of the 2017-2018 program period stand in stark contrast with the models for the two earlier periods. In the 2017-2018 period the ESKs were estimated to generate 4.4 therm savings. For each shower wand that was delivered an additional 7.7 therm savings was estimated. Savings estimates using the future participant group are higher but the number of future participants for this time period is significantly smaller. We therefore focus on the results of the matched comparison group. When adjusting the savings for installation rates and more than one product being delivered the savings associated with an installed showerhead are 5.3 therms and those of an installed shower wand 14.08.

5.12 Conclusion

The Recurve analysis is by its nature quite simple as it is a comparison of means. The regressions analyses done in this report are also quite simple but add some additional insight into the results by segmenting the analysis with available characteristics data. Analyzing the program's different time periods indicated that estimated ESK savings were considerably higher in the later period possibly indicating differences in program delivery. Differentiating between showerheads and shower wands also led to different estimates of savings. The other regressions that split the analysis on geography, site specific characteristics, census tract characteristics did not reveal other significant factors that influenced savings estimates for the showerheads or shower wands.